TITLE OF THE INVENTION

ELECTRON BEAM LITHOGRAPHY APPARATUS

FIELD OF THE INVENTION

5   The present invention relates to an electron beam
lithography apparatus and, more particularly, to an
electron beam lithography apparatus in which a leakage
magnetic field from a stage driving mechanism that uses
a permanent magnet is shielded to realize accurate
10   lithography.

BACKGROUND OF THE INVENTION

In recent years, along with an increase in degree
of integration of semiconductor elements, demand for a
15   finer design rule has arisen. An electron beam
lithography apparatus directly draws a fine pattern on
a sample surface by converging an electron beam by an
electron lens and deflecting it by a deflector.

The stage of the electron beam lithography
20   apparatus is required to be able to operate under
high-vacuum environment and be made of a non-magnetic
material that does not change the electron beam
position on the sample.

A factor that degrades the beam position accuracy
25   due to a laser measurement system used for stage
position control is Abbe error. This Abbe error is

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given by (change amount of stage posture) × (offset amount between the position to be drawn and laser measurement optical axis). For example, to suppress the Abbe error to 5 nm when the offset amount of the laser measurement optical axis is 1 mm, the allowable value of the stage posture change amount is 1 sec (= 5 μrad). Conventionally, a rolling guide made of a non-magnetic cemented carbide alloy (to be referred to as a cemented carbide material hereinafter) as described in Japanese Patent Laid-Open No. 05-198469 is used as a stage guide. However, since the stage posture changes due to straightness errors of the guide, it is very difficult to suppress pitch/yaw/roll to 1 arc-sec or less.

In addition, since a ceramic table is softer than a rolling element formed from cemented carbide, the table slightly deforms as the rolling element moves. As a result, the distance between the sample and a measurement mirror changes on the nanometer order, and measurement errors occur. As described above, the position accuracy of a lithography pattern degrades due to Abbe errors or small deformation of the stage.

Such degradation in position accuracy is caused by a change in stage posture and the deformation amount of the stage. In consideration of this problem, when an air bearing guide for vacuum environment is used as

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a stage guide, a stage posture change of 1 sec or less can be achieved as long as the surface accuracy of the guide surface plate is on the submicron order. Additionally, since this stage guide is a non-contact moving mechanism, the deformation amount of the table is small. An air bearing guide for polygon mirror working machine, which is disclosed in Japanese Patent Laid-Open No. 10-217053 sometimes uses a permanent magnet in the stage as a pre-load applying means for preventing a change in stage posture. This permanent magnet attracts the stage main body to the guide surface plate side. A non-contact constraint means using the repelling force between permanent magnets in vacuum, which is disclosed in Japanese Patent Laid-Open No. 10-281110, is also effective to prevent the table from deforming as the stage moves. However, if the external leakage magnetic field from the permanent magnet is not shielded, the static magnetic field distribution of the permanent magnet moves as the stage moves, resulting in positional shift of the electron beam on the sample.

The allowable magnetic field change amount will be estimated from the viewpoint of electron beam position accuracy with reference to Fig. 4. Any variation in magnetic field present in the space between an electron lens 5 and a sample 7 changes the

position illuminated by an electron beam 4. Let H be the distance from the lower surface of the electron lens 5 to the sample 7, and $\Delta B(T)$ be the variation amount of the magnetic field in this space. Electrons

5 that have passed through the electron lens 5 are affected by the variation in magnetic field, deflected by a deflection angle θ along an orbit with a Bohr radius R, and reach a point separated from the target irradiation position by ΔX.

10 Where the deflection angle θ is sufficiently small, ΔX can be approximated by

$$\Delta X = H^2/(2R) \qquad \ldots (1)$$

The Bohr radius R is given by

$$R = mv/(e\Delta B) \qquad \ldots (2)$$

15 where m: the mass of electrons $m = 9.1 \times 10^{-31}$ (kg)

e: the charge of electrons $e = 1.6 \times 10^{-19}$ (C)

v: the velocity of electrons

Substitution of the Bohr radius into equation (1) yields

20 $$\Delta X/\Delta B = eH^2/(2mv) \qquad \ldots (3)$$

On the other hand, the energy of electrons is given by

$$E = mv^2/2 \ldots (4)$$

Elimination of v from equations (3) and (4) yields

25 $$\Delta X/\Delta B = eH^2/(2\sqrt{(2mE)}) \qquad \ldots (5)$$

Fig. 5 is a graph showing the relationship

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(calculation values) between the beam position shift and the magnetic field when the acceleration voltage is used as a parameter assuming $\Delta X = 10$ nm and $H = 25$ mm. When a change in magnetic field is 2×10^{-8} T or less,

5 and the acceleration voltage is 30 kV or more, the positional shift of the beam is 10 nm or less. Hence, the leakage magnetic field from the permanent magnet must be shielded such that it becomes 2×10^{-8} T or less.

On the other hand, the leakage magnetic field

10 from the electron lens is always present in the space under the electron lens. A shield member formed from a ferromagnetic material moves in the leakage magnetic field of the electron lens. This disturbs the magnetic field in the space from the lower surface of the

15 electron lens to the sample and causes a positional shift of electron beam on the sample. To reduce this positional shift amount, the leakage magnetic field from the electron lens must also be made small.

For accurate lithography, both the leakage

20 magnetic field from the permanent magnet and that from the electron lens must be shielded, and the magnetic field change amount at the sample position must be reduced to 2×10^{-8} T or less.

25 SUMMARY OF THE INVENTION

It is therefore an object of the present

invention to provide an electron beam lithography apparatus suitable for accurate lithography and to provide an apparatus structure capable of reducing the magnetic field change amount at the sample position to

5   2×10^{-8} T or less.

In order to achieve the above object, according to the present invention, a leakage magnetic field from a permanent magnet in a stage main body is reduced by shielding all surfaces of the permanent magnet except

10   the attracting surface by a ferromagnetic material.

A leakage magnetic field generated when a shield moves in a leakage magnetic field from an electron lens is reduced by providing a shield for reducing the leakage magnetic field from the electron lens on the

15   lower surface of an electron optical lens-barrel.

With the above-described two shield means, even when the stage moves, the external leakage magnetic field from the permanent magnet or electron lens does not affect the electron beam irradiation position, and

20   accurate lithography can be realized.

Other features and advantages of the present invention will be apparent from the following description taken in conjunction with the accompanying drawings, in which like reference characters designate

25   the same or similar parts throughout the figures thereof.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are incorporated in and constitute a part of the specification, illustrate embodiments of the invention and, together with the description, serve to explain the principles of the invention.

Fig. 1 is a sectional view showing the schematic arrangement of a portion under the electron optical lens-barrel of an electron beam lithography apparatus according to the first embodiment of the present invention;

Fig. 2 is a sectional view schematically showing the overall arrangement of the electron beam lithography apparatus;

Figs. 3A to 3C are plan, sectional, and enlarged views, respectively, showing a conventional sample stage;

Fig. 4 is a view for explaining a state in which the path or trajectory of an electron beam is changed by a uniform magnetic field present in a space above a sample;

Fig. 5 is a graph showing the relationship between the magnetic field change amount and the electron beam irradiation position shift;

Figs. 6A and 6B are plan and sectional views, respectively, showing the structure of an air pad of

the first embodiment;

Figs. 7A and 7B are plan and side views, respectively, showing the structure of a permanent magnet (multi-pole magnet) of the first embodiment;

Fig. 8 is a view showing the emission state of lines of magnetic force from the multi-pole magnet shown in Fig. 7;

Fig. 9 is a view showing the layout of a single-layered shield of the first embodiment;

Fig. 10 is a view showing the layout of multiple shields of the first embodiment;

Fig. 11 is a graph showing the leakage magnetic field reduction effect of a magnetic field shield structure of the first embodiment;

Fig. 12 is a sectional view showing the influence of the electron lens leakage magnetic field on the magnetic field shield structure in the first embodiment;

Fig. 13 is a view showing the disturbance in unique magnetic field by a magnetic field shield made of a ferromagnetic material;

Fig. 14 is a graph showing the shield effect of the electron lens leakage magnetic field shield;

Fig. 15 is a view showing the structure of a sample stage portion in an electron beam lithography apparatus according to the second embodiment of the

present invention;

Fig. 16 is a cross-sectional view showing a structure taken along a line C - C' in Fig. 15;

Fig. 17 is a view showing the structure of a sample stage portion in an electron beam lithography apparatus according to the third embodiment of the present invention;

Fig. 18 is a view showing the structure of a sample stage portion in an electron beam lithography apparatus according to the fourth embodiment of the present invention;

Fig. 19 is a view showing the structure of a sample stage portion in an electron beam lithography apparatus according to the fifth embodiment of the present invention;

Fig. 20 is a cross-sectional view showing a structure taken along a line D - D' in Fig. 19;

Figs. 21A and 21B are plan and sectional views, respectively, showing the structure of a sample stage portion in an electron beam lithography apparatus according to the sixth embodiment of the present invention;

Fig. 22 is a plan view showing the structure of a sample stage portion in an electron beam lithography apparatus according to the seventh embodiment of the present invention;

Fig. 23 is a plan view showing the structure of a sample stage portion in an electron beam lithography apparatus according to the eighth embodiment of the present invention;

5   Figs. 24A and 24B are plan and sectional views, respectively, showing the structure of a sample stage portion in an electron beam lithography apparatus according to the ninth embodiment of the present invention;

10   Fig. 25 is an enlarged view showing the detailed structure of a portion G shown in FIG. 24B; and

Figs. 26A to 26D are sectional views showing a method of manufacturing a semiconductor integrated circuit element using the electron beam lithography 15   apparatus of the present invention as the 10th embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The embodiments of the present invention will be 20   described below in detail with reference to the accompanying drawings.

To minimize the leakage magnetic field from a magnet incorporated in the stage main body as much as possible, the lines of magnetic force from the magnet 25   are designed to form a closed loop. For, e.g., a multi-pole magnet having alternate N and S poles, when

the magnet is attached to a yoke made of a
ferromagnetic material, the lines of magnetic force
from the N and S poles cancel each other to greatly
reduce the leakage magnetic field on the yoke

5   attachment surface. Similarly, when the attracting
surface is set close to the surface plate, the lines of
magnetic force from the N and S poles cancel each other
to reduce the leakage magnetic field. However, when
the magnetic field of the magnet itself is 1 T or more,

10   changes in magnetic field can hardly be reduced to the
allowable value of 2×10^{-8} T or less.

To reduce the leakage magnetic field of the
magnet, all surfaces of the magnet, excluding the
attracting surface, are shielded by a ferromagnetic

15   material having high permeability. Since the
ferromagnetic material is magnetized upon machine
working, it must be heated and demagnetized after
working.

To reduce the leakage magnetic field of a

20   permanent magnet, the generated magnetic field is
reduced by forming a closed loop of lines of magnetic
force, and the generated magnetic field is shielded.

On the other hand, to reduce disturbance in
leakage magnetic field of an electron lens along with

25   movement of a magnetic field shield, a magnetic field
shield is provided under an electron optical

lens-barrel while preventing any influence on deflection for lithography.

When both the generated magnetic field of the electron lens and that of the permanent magnet are shielded, the magnetic field variation amount at the sample position can be suppressed to the allowable value of 2×10^{-8} T or less for electron beam lithography.

<First Embodiment>

Fig. 1 is a sectional view showing the schematic arrangement of a portion under the electron optical lens-barrel of an electron beam lithography apparatus according to the first embodiment of the present invention.

Fig. 2 is a sectional view schematically showing the overall arrangement of the electron beam lithography apparatus. The interior of an electron optical lens-barrel 1 and that of a sample chamber 2 are held in vacuum. An electron beam 4 from an electron gun 3 in the electron optical lens-barrel 1 is converged by an electron lens 5 and deflected by a deflector 6 so that a predetermined position on a sample 7 is irradiated with the electron beam. The sample 7 is placed on a sample stage 8 in the sample chamber 2. When the surface of the sample 7 is irradiated with the electron beam 4 deflected and

scanned while moving the sample stage 8 by a stage driver 20, a desired pattern can be drawn on the entire surface of the sample 7.

Figs. 3A to 3C are plan, sectional, and enlarged views, respectively, showing a conventional sample stage. Referring to Figs. 3A to 3C, a sample 7 and stage position measurement bar mirrors 10 are placed on a Y-table 9. In lithography, the sample position is obtained by measuring the positions of the bar mirrors 10 by laser measurement.

The Y-table 9 and X-table 11 have the relationship as shown in the sectional view of Fig. 3B taken along a line A - A' in Fig. 3A. Cemented carbide guides 12 are attached to the inner surfaces of the concave portion of the X-table 11 and the outer surfaces of the convex portion of the Y-table 9, respectively. The cemented carbide guides 12 have V-grooves on their opposing surfaces. A crossed roller 13 is inserted between each pair of V-grooves. The Y-table 9 moves relative to the X-table 11 through the crossed rollers 13. As shown in Fig. 3C or an enlarged view of a portion B, the crossed roller 13 has a plurality of column-shaped rollers 14 whose directions alternate by 90°. The X-table 11 and a base 15 also have, therebetween, the same structure as described above. The X-table 11 moves relative to the base 15

through the crossed rollers 13.

Since the Y-table 9 moves while rotating the rollers 14, the convex portion of the Y-table 9 receives a compression force from the rollers 14. When this compression force varies, the Y-table 9 made of a ceramic slightly deforms by about 50 nm at maximum. Since this deformation changes the positions of the sample 7 and bar mirrors 10, the irradiation position accuracy of the electron beam 4 degrades, as is known.

In the first embodiment, under vacuum environment, while a stage 16 is supported to float by the force of air blown from an air pad, the floating stage 16 is attracted to a surface plate 18 by the attracting force of a permanent magnet 17, as shown in Fig. 1.

An air pad 19 which simultaneously blows and draws a gas is attached to the bottom surface of the stage 16. The stage 16 is attracted to the surface plate 18 by the attracting force of the permanent magnet 17 serving as a pre-load applying means. The stage 16 is driven by the stage driver 20 and moves along the upper surface of the surface plate 18. Since the floating position of the stage 16 is determined by balancing the attracting force of the permanent magnet 17 and the reaction (floating force) of the air stream, the rigidity of the stage 16 in running is maintained.

To prevent influence of the magnetic field of the

permanent magnet 17 on the electron beam irradiation position, all surfaces of the permanent magnet 17 except the attracting surface are shielded by a magnetic field shield 21. In addition, to reduce the

5 leakage magnetic field from the electron lens 5 into the sample chamber 2, an electron lens leakage magnetic field shield 22 is attached to the lower surface of the electron optical lens-barrel 1.

Figs. 6A and 6B are views showing the structure

10 of the air pad 19. Fig. 6A is a plan view showing the air pad 19 from the lower side. Fig. 6B is a sectional view taken along a line A - A' in Fig. 6A. The air pad 19 has a blow port 23 and suction ports 24. A gas is blown from the blow port 23 to apply a floating force

15 to the stage 16 and float it on the surface plate 18. The blown gas is recovered from the suction ports 24.

Figs. 7A and 7B are views showing a multi-pole magnet structure as the permanent magnet 17. Fig. 7A is a plan view showing the permanent magnet 17 from the

20 lower side. Fig. 7B is a side view. A plurality of plate magnets 25 are polarized in the vertical direction (direction perpendicular to the surface plate surface). N and S poles alternate on the lower surface (attracting surface) side of the magnets. The upper

25 surface (surface on the opposite side of the attracting surface) of each magnet is fixed to a yoke 26. This

yoke 26 reduces the leakage magnetic field to the upper side of the magnets.

As shown in Fig. 8, on the yoke 26 side, the poles of the plate magnets 25 are short-circuited by the yoke 26, so almost no lines of magnetic force leaks from the yoke 26 to the external space. However, on the attracting surface side, the lines of magnetic force run from the N poles to the S poles through the external space.

Fig. 9 is a view showing the layout of the surface plate 18, plate magnets 25, and magnetic field shield 21 when the stage 16 is floating. When the distance between the plate magnets 25 and the surface plate 18 and that between the magnetic field shield 21 and the surface plate 18 are set to t1 and t2 (t1 and t2 > 0), respectively, some lines of magnetic force leak from the shield 21 to the external space through the gap. To more effectively reduce the leakage magnetic field to the external space, the magnetic field shield 21 may have a multiple structure. Referring to Fig. 10, an inner shield 27 (gap: t2) is provided immediately outside the yoke 26 and an outer shield 28 (gap: t3) is provided outside the inner shield 27 via a space.

Fig. 11 is a graph showing the leakage magnetic field strength to the external space when the heights

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(gaps: t1, t2, and t3) from the upper surface of the surface plate 18 to the plate magnets 25, inner shield 27, and outer shield 28 are set to 0.1 mm in the layout shown in Fig. 10. The magnetic field strength curves

5   shown in Fig. 11 are calculated from

$$B = Pm/(4\pi\mu_0 H^2) \qquad \qquad \ldots (6)$$

where B: magnetic field strength

Pm: magnetic moment of magnetic dipole (magnet)

10   μ_0: permeability in vacuum/μ_0 = 1.3 $\times$ 10^{-6} (H/m)

H: distance from the magnetic dipole (magnet). This equation represents that the actual measurement value of magnetic field strength and the magnetic field strength are in reverse proportion to the square of

15   distance at a specific position outside the permanent magnet in the horizontal direction.

As is apparent from Fig. 11, at a position separated from the permanent magnet by 100 mm, when no shield structure is provided, the leakage magnetic

20   field strength from the permanent magnet decreases to only 1 $\times$ 10^{-6} T. When the shield structure shown in Fig. 10 is employed, it decreases to 2 $\times$ 10^{-8} T. This fact reveals that a sufficient reduction effect (shield effect) for the leakage magnetic field from the

25   permanent magnet can be obtained by the shield structure shown in Fig. 10.

As shown in Fig. 12, the leakage magnetic field from the electron lens 5 is present under the electron lens 5. When the above-described magnetic field shield 21 is placed in this leakage magnetic field, the

5   magnetic field in a region around the magnetic field shield 21 made of a ferromagnetic material is disturbed, as shown in Fig. 13, to change the magnetic field on the sample 7, and this change in magnetic field on the sample 7 causes an irradiation position shift of the

10   electron beam 4. To prevent this change in magnetic field on the sample, the leakage magnetic field from the electron lens 5 must be reduced.

In this embodiment, the electron lens leakage magnetic field shield 22 is provided beneath the

15   electron lens 5. Fig. 14 is a graph showing the leakage magnetic field shield effect in this case. The maximum magnetic field strength in the electron lens 5 (height position: h1) is 10^{-2} T. The leakage magnetic field strength attenuates as the distance from the

20   electron lens 5 increases. If the shield 22 is not provided, the magnetic field strength is 10^{-4} T at a sample height position h2 and 10^{-6} T at a height position h3 of the shield 21. In this case, the magnetic field variation amount generated along with

25   the movement of the magnetic field shield 21 exceeds 10^{-8} T, resulting in a shift in irradiation position of

the electron beam 4 on the sample 7.

When the shield 22 of the present invention is provided, the leakage magnetic field strength from the electron lens 5 can be reduced to 10^{-8} T at the position

5   of the sample 7 and 10^{-11} T at the position of the shield 21. For this reason, the magnetic field variation amount generated along with the movement of the magnetic field shield 21 is inevitably 10^{-11} T or less. This magnetic field variation amount hardly

10   affects the irradiation position of the electron beam 4 on the sample 7.

With the above arrangement, the height position and posture of the sample stage 16 can be controlled in a non-contact state, and the leakage magnetic field

15   from the permanent magnet 17 and electron lens 5 can be prevented from affecting the electron beam irradiation position. Hence, accurate lithography can be realized.

To further increase the leakage magnetic field shield effect in the arrangement shown in Fig. 9,

20   letting t1 be the distance between the surface plate 18 and the plate magnets 25 serving as a magnetic force constraint means, and t2 be the distance between the surface plate 18 and the magnetic field shield 21, the plate magnets 25 and magnetic field shield 21 are

25   preferably laid out relative to the surface plate 18 such that t1 > t2 holds. To further increase the

leakage magnetic field shield effect in the arrangement shown in Fig. 10, t1 > t2 and t1 > t3 preferably hold.

<Second Embodiment>

Fig. 15 is a view showing the structure of a stage portion in an electron beam lithography apparatus according to the second embodiment of the present invention. This embodiment is related to a magnetic field shield structure employed when a single-axis linear motor is used to drive the stage.

Referring to Fig. 15, a sample 7 is placed on a stage 16. Rollers 14 are inserted between a surface plate 18 and the stage 16. A power transmission frame 29 is attached to the stage 16 main body. A driving coil 30 is fixed to the end portion of the power transmission frame 29. Permanent magnets 31 and 32 are arranged on both sides of the driving coil 30. The permanent magnets 31 and 32 are attached to the inner walls of a fixed yoke 33 which also serves as a guide. According to the principle of the single-axis linear motor shown in Fig. 15, a driving force is generated by interaction between the fixed magnetic field generated by the permanent magnets 31 and 32 and the current by the movable driving coil 30. (Fleming's rule)

The leakage magnetic field from the permanent magnets 31 and 32, and the magnetic field generated by the current of the coil 30 can be reduced using a

high-permeability material for the fixed yoke 33 which surrounds the permanent magnets 31 and 32. For the magnetic field generated by the current of the driving coil 30, the leakage magnetic field to the external

5 space is reduced by providing a movable yoke 34 made of a high-permeability material on the lower surface of the driving coil 30. An example of the high-permeability material is Permalloy.

Fig. 16 is a cross-sectional view showing a

10 section taken along a line C - C' in Fig. 15. When a current is flowed to the driving coil 30, an attracting force acts between the driving coil 30 and permanent magnets 35 and 36 while a repelling force acts between the driving coil 30 and permanent magnets 37 and 38.

15 In accordance with the force, the driving coil 30 receives a force for moving itself in one direction (to the left in Fig. 16).

In the structure shown in Fig. 15, the stage 16 is supported and guided by the rollers 14 on the

20 surface plate 18. However, the present invention is not limited to this, and the stage 16 may be supported by needle roller guides, crossed roller guides, or air bearing guides.

<Third Embodiment>

25 Fig. 17 is a view showing the structure of a stage portion in an electron beam lithography apparatus

according to the third embodiment of the present
invention. In this embodiment, permanent magnets 31
and 32 which construct a stage driving linear motor are
surrounded by a fixed yoke 39 made of a ferromagnetic

5   material, thereby reducing the external leakage
magnetic field from the permanent magnets 31 and 32.
In addition, a fixed shield 40 made of a
high-permeability material is provided around the fixed
yoke 39, thereby shielding the leakage magnetic field

10 from the fixed yoke 39. For the magnetic field
generated from a movable driving coil 30 as well, the
external leakage magnetic field is reduced by a movable
yoke 41 made of a ferromagnetic material and a movable
shield 42 made of a high-permeability material. An

15 example of the ferromagnetic material is an iron-based
material. An example of the high-permeability material
is Permalloy.

The double shield structure of this embodiment is
more effective to prevent external leakage of the

20 strong magnetic field generated in the linear motor.
<Fourth Embodiment>

Fig. 18 is a view showing the structure of a
stage portion in an electron beam lithography apparatus
according to the fourth embodiment of the present

25 invention. In this embodiment, the magnetic field
generated by permanent magnets 31 and 32 in the stage

driving linear motor is reduced by a fixed yoke 43

formed from a high-permeability material. In addition,

the magnetic field is shielded by a fixed shield 45

made of a high-permeability material through a spacer

5   44 made of a non-magnetic material. For the magnetic

field generated by a movable driving coil 30 as well,

the external leakage magnetic field is reduced by

providing a movable shield 46 made of a

high-permeability material. For example, Permalloy can

10   be used as the high-permeability material. The double

shield structure of this embodiment can more

effectively prevent the magnetic field from the stage

driving system from directly leaking to the external

space.

15   <Fifth Embodiment>

Fig. 19 is a view showing the structure of a

stage portion in an electron beam lithography apparatus

according to the fifth embodiment of the present

invention. This embodiment is related to a structure

20   capable of making a shield member more compact and

lightweight.

In this embodiment, a movable yoke 60 formed from

a high-permeability material is fixed to the

linear-motor-side end portion of a power transmission

25   frame 29 which connects the sample stage and linear

motor, and permanent magnets 31 and 32 are attached to

opposing inner surfaces of the movable yoke 60.

Between the opposing surfaces of the permanent magnets

31 and 32, a driving coil 30 is fixed on a surface

plate 18 via a fixed yoke 61. That is, in this

5   embodiment, the movable portion is formed on the side

of the yoke 60 and permanent magnets 31 and 32 of the

linear motor while the fixed portion is formed on the

side of the yoke 61 and driving coil 30, unlike the

above-described embodiments. The driving coil 30 is an

10   coreless coil and has no magnetic core made of a

ferromagnetic material. Hence, this driving coil 30

does not generate a magnetic field unless it is

energized.

       Fig. 20 is a cross-sectional view showing a

15   structure taken along a line D - D' in Fig. 19.

Referring to Fig. 20, the driving coil comprises a

plurality of driving coils 30a to 30f. The length of

the movable yoke 60 in its moving direction is set to a

length that allows the yoke 60 to surround driving

20   coils (two driving coils 30c and 30d energized for

driving) interacting with the permanent magnets 31 and

32 whereby the leakage magnetic field generated upon

electromagnetically driving the stage can be shielded.

       As described above, since driving coils (driving

25   coils 30a, 30b, 30e, and 30f in Fig. 20) which are not

surrounded by the movable yoke 60 are not energized and

generate no magnetic field, no leakage magnetic field is generated from these portions. In the above-described second to fourth embodiments, a region almost equal to the entire moving range of the stage

5   must be shielded by a member made of a high-permeability material. In this embodiment, however, since the movable permanent magnets 31 and 32 need be shielded, and only two driving coils (driving coils 30c and 30d in Fig. 20) interacting (energized)

10   with the permanent magnets need be shielded, the required shield range becomes narrow, and the shield member can be made more compact and lightweight, as compared to the second to fourth embodiments. In addition, when only the two end portions of the driving

15   coil group comprising the driving coils 30a to 30f in Fig. 20 are supported, the movable yoke shown in Fig. 19 can have a shape completely closed around the moving axis, and the leakage magnetic field from the permanent magnets 31 and 32 in the movable yoke can be

20   further reduced.

<Sixth Embodiment>

    Figs. 21A and 21B are views showing the structure of a stage portion in an electron beam lithography apparatus according to the sixth embodiment of the

25   present invention. Fig. 21A is a plan view of the stage portion when viewed from the upper side.

Fig. 21B is a sectional view taken along a line E - E'
in Fig. 21A. In this embodiment, the stage having a
leakage magnetic field shield for the pre-load applying
permanent magnet in the first embodiment is driven by
5   the linear motor according to one of the second to
fifth embodiments.

In this embodiment, three single-axis linear
motors are combined in an H shape such that a sample
stage 16 can be two-dimensionally driven in the X and Y
10   directions, as shown in Figs. 21A and 21B. More
specifically, the stage 16 is driven in the Y direction
by two linear motors Y1 and Y2 and in the X direction
by a linear motor X1.

In the linear motor Y1, a Y1 moving element 48
15   moves in the Y direction along a Y1 guide 47. In the
linear motor Y2, a Y2 moving element 50 moves in the Y
direction along a Y2 guide 49. The two ends of an X1
guide 51 of the linear motor X1 are connected to the Y1
moving element 48 and Y2 moving element 50,
20   respectively, so that the linear motor X1 is moved in
the Y direction by synchronous operation of the Y1
moving element 48 and Y2 moving element 50. In the
linear motor X1, an X1 moving element 52 on which the
sample stage 16 is mounted moves in the X direction
25   along the X1 guide 51.

With the above driver arrangement, the sample

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stage 16 can two-dimensionally move in the X and Y directions, so lithography across the entire surface of a sample 7 can be realized. The two-dimensional position of the sample stage 16 is measured by

5   measuring the X- and Y-direction positions of two bar mirrors 10 fixed on the sample stage 16 using a laser interferometer.

The leakage magnetic field strength from the linear motor decreases as the distance from the X1

10   moving element 52 increases. At the position of the sample 7 on the stage 16, the leakage magnetic field attenuates to a level that does not affect the electron beam irradiation position accuracy.

According to this embodiment, when the sample

15   stage 16 is supported in a non-contact state, the portion that holds the sample 7 hardly deforms, and the sample 7 is not distorted. For this reason, accurate lithography can be realized. In addition, since the outer dimensions of the sample chamber can fall within

20   the stage moving range and the installation area of the linear motors, a compact apparatus can be realized.
<Seventh Embodiment>

Fig. 22 is a plan view showing the structure of a stage portion in an electron beam lithography apparatus

25   according to the seventh embodiment of the present invention. The structure of the linear motor is the

same as in the above-described sixth embodiment.

In the structure of the sixth embodiment, the sample stage 16 sometimes moves immediately under the electron optical lens-barrel during lithography. The leakage magnetic field from the electron lens is maximized at this position immediately under the electron optical lens-barrel. When the X1 moving element 52 moves to this position, an eddy current flows in the X1 moving element 52 made of a ferromagnetic material in accordance with the magnitude of the leakage magnetic field from the electron lens or the stage velocity. The magnetic field generated by this eddy current also degrades the electron beam irradiation position accuracy on the sample surface.

In the seventh embodiment, to suppress the eddy current flow to an X1 moving element 52, the X1 moving element 52 is attached to the side surface of a stage 16 main body such that the X1 moving element 52 does not come to the position immediately under the electron optical lens-barrel in the stage moving range. With this layout, the influence of the magnetic field generated when the eddy current flows to the X1 moving element 52 can be reduced, and accurate lithography can be realized.

<Eighth Embodiment>

Fig. 23 is a plan view showing the structure of a

stage portion in an electron beam lithography apparatus according to the eighth embodiment of the present invention.

In the stage structure of the above-described seventh embodiment, when the stage 16 is accelerated/decelerated in the X direction, the inertial force of the stage 16 acts on the X1 moving element 52, so the posture of the stage 16 readily changes in the yaw direction. In the eighth embodiment, two linear motors X1 and X2 for X-direction drive are arranged on both sides of a stage 16. In the linear motor X1, an X1 moving element 52 moves in the X direction on an X1 guide 51. In the linear motor X2, an X2 moving element 71 moves in the X direction on an X2 guide 70. The end portions of the X1 guide 51 and X2 guide 70 are coupled to a Y1 moving element 48 and Y2 moving element 50, thereby increasing the support rigidity and driving rigidity of the stage 16.

With the above structure, since the influence of the leakage magnetic field from the linear motors on the electron beam irradiation position accuracy can be suppressed, and stage movement with high support rigidity in the X direction can be realized, high-speed, accurate lithography can be executed.

<Ninth Embodiment>

Figs. 24A and 24B are plan and sectional views,

respectively, showing the structure of a stage portion in an electron beam lithography apparatus according to the ninth embodiment of the present invention.

In this embodiment, to reduce the influence of the leakage magnetic field from the pre-load applying permanent magnet 17 used in the first embodiment and the leakage magnetic field of the linear motor X1 moving element 52 used in the second to eighth embodiments, a complete-constraint-type air bearing guide is used instead of the permanent magnet, and a linear motor is separated from a sample 7.

As shown in Fig. 25, a single-axis air bearing is constructed by a static-pressure guide 72 and static-pressure moving element 73. Air pads 19 are attached inside the static-pressure moving element 73. Each air pad 19 has a blow port 23 and suction ports 24 and obtains a reaction (floating force) from the force of gas blown from the blow port 23. When the reactions of four air pads 19 balance, the degrees of freedom of the static-pressure moving element 73 except the moving direction are constrained. The blown gas is recovered from the suction ports 24.

Referring to Figs. 24A and 24B, an air bearing Y1 is constructed by a Y1 static-pressure guide 74 and Y1 static-pressure moving element 75. The Y1 static-pressure moving element 75 can move with respect

to the Y1 static-pressure guide 74 without slip. An

air bearing Y2 is constructed by a Y2 static-pressure

guide 76 and Y2 static-pressure moving element 77. An

X1 static-pressure guide 78 is fixed to the Y1

5   static-pressure moving element 75 and Y2

static-pressure moving element 77. An X1

static-pressure moving element 79 can move with respect

to the X1 static-pressure guide 78.

The Y1 static-pressure moving element 75 of the

10   air bearing Y1 is driven by a linear motor LY1. An LY1

moving element 48 of the linear motor LY1 is coupled to

the Y1 static-pressure moving element 75. An LY1 guide

47 of the linear motor LY1 is arranged parallel to the

Y1 static-pressure guide 74 of the air bearing Y1. In

15   arranging the Y1 static-pressure guide 74 and LY1 guide

47 in parallel, a small parallelism error occurs.

However, since the allowable value of the positional

shift between the LY1 moving element 48 and the LY1

guide 47 is several mm, the LY1 moving element 48

20   follows the track of the Y1 static-pressure moving

element 75. Additionally, in this embodiment, to

suppress the leakage magnetic field from the linear

motor and magnetic field generated by an eddy current,

the linear motor LY1 is arranged on the opposite side

25   of the sample 7 with respect to the air bearing Y1,

i.e., as a position more separated from the sample 7.

The method of driving the Y2 static-pressure
moving element 77 of the air bearing Y2 is the same as
described above. The Y2 static-pressure moving element
77 is driven by a linear motor LY2 constructed by an
5   LY2 guide 49 and LY2 moving element 50.

The X1 static-pressure moving element 79 of the
air bearing X1 is driven by a linear motor LX1. The
two end portions of an LX1 guide 51 of the linear motor
LX1 are coupled to the Y1 static-pressure moving
10   element 75 and Y2 static-pressure moving element 77,
respectively. For the linear motor LX1 as well, to
reduce the leakage magnetic field therefrom and a
magnetic field generated by an eddy current, the linear
motor LX1 is arranged below the air bearing X1.

15   As described above, when an X-Y stage constrained
to float by the complete-restriction-type air bearing
guide is driven by three linear motors separated from
the position of the sample 7, the leakage magnetic
field from the linear motors can be reduced, and the
20   magnetic field generated by the eddy current in moving
the linear motor moving elements (ferromagnetic
material) can be suppressed. Hence, accurate
lithography can be realized.

<10th Embodiment>

25   Figs. 26A to 26D are sectional views showing
steps in manufacturing a semiconductor integrated

circuit element using the electron beam lithography
apparatus of the present invention as the 10th
embodiment of the present invention. Figs. 26A to 26D
are element sectional views showing steps in

5   manufacturing the element.

An experimental embodiment will be shown here. A
lithography method using the electron beam lithography
apparatus of the present invention was applied not to
all pattern formation processes but to only the

10   patterning process of a photosensitive agent 109 shown
in Fig. 26C. For the remaining processes, the
conventional lithography method was used and compared
with the effect of the present invention.

First, a p-well layer 101, p-layer 102, field

15   oxide film 103, polysilicon/silicon oxide film gate 104,
heavily doped p-diffusion layer 105, and heavily doped
n-diffusion layer 106 were formed on an n^--silicon
substrate 100 by the conventional method (Fig. 26A).

An insulating film 107 of phosphosilicate glass

20   (PSG) was formed and removed by dry etching to form
contact holes 108 (Fig. 26B).

After a material for a W/TiN electrode
interconnection 110 was formed by the conventional
method, the photosensitive agent 109 was coated thereon.

25   The photosensitive agent 109 was patterned by the
electron beam lithography method using the electron

beam lithography apparatus of the present invention.
The W/TiN electrode interconnection 110 was formed by,
e.g., dry etching (Fig. 26C).

5 An insulating interlayer 111 was formed. A hole
pattern 112 was formed by the conventional method. A W
plug was buried in the hole pattern 112. A second Al
interconnection 113 was connected to the W plug
(Fig. 26D). The conventional method was used in the
subsequent passivation process.

10 In this embodiment, only main manufacturing
processes have been described. The same method as in
the prior art was used except in the lithography
process for W/TiN electrode interconnection formation
for which the electron beam lithography method of the
15 present invention was used. With the above processes,
a fine pattern was accurately formed, and CMOS LSIs
were manufactured at high yield. When semiconductor
integrated circuit elements were manufactured using the
electron beam lithography apparatus of the present
20 invention, resolution errors in interconnections could
be prevented, and the yield of non-defective products
largely improved.

According to the present invention, since the
support/guide mechanism of the sample stage has a
25 non-contact structure, the table member on which a
sample is placed can be prevented from deforming as the

stage moves, and the stage can be accurately moved. Hence, accurate lithography can be realized.

As many apparently widely different embodiments of the present invention can be made without departing from the spirit and scope thereof, it is to be understood that the invention is not limited to the specific embodiments thereof except as defined in the appended claims.